Answer on Question #53381, Physics / Mechanics | Kinematics | Dynamics

Crank on an engine has rotating parts of mass 4.25kg, with a radius of gyration k = 59 mm. Determine the torque in Nm required to overcome the inertia of the rotating parts when angular acceleration is 36 $\frac{\mathrm{rad}}{\mathrm{s}^2}$.

Solution:

Angular acceleration, also called rotational acceleration, is a quantitative expression of the change in angular velocity that a spinning object undergoes per unit time. It is a vector quantity, consisting of a magnitude component and either of two defined directions or senses. The magnitude, or length, of the angular acceleration vector is directly proportional to the rate of change of angular velocity, and is measured in radians per second squared ($\frac{\mathrm{rad}}{\mathrm{s}^2}, \mathrm{rad} \cdot \mathrm{s}^{-2}$).

When we rotate a wheel, we must apply torque to overcome the inertia and speed it up or slow it down. We should know that torque is a moment of force. A force applied to the axle of a wheel will not make it rotate. A force applied at a radius will.

All rotating machinery such as pumps, engines and turbines have a moment of inertia. The radius of gyration is the radius at which we consider the mass to rotate such that the moment of inertia is given by

$$\mathrm{I} = \mathrm{Mk}^2$$

Where M is the total mass and k is the radius of gyration.

Thus, we can determine the moment of inertia by substituting the values according to the condition of the task.

$$\mathrm{I} = \mathrm{Mk}^2 = 4.25\mathrm{kg} \cdot (0.059\mathrm{m})^2 = 0.003481 \cdot 4.25 = 0.01479425\ \mathrm{kg} \cdot \mathrm{m}^2$$

Hence in order to accelerate rotating parts with angular acceleration α, a torque T is required and the relationship is

$$\mathrm{T} = \mathrm{I}\alpha$$

This is Newton's 2nd law written in angular terms and it applies to any shape, not just plain discs.

Thus, we finally can determine the torque in Nm required overcoming the inertia of the rotating parts. We substitute the value of an angular acceleration into the formula noted above.

$$\mathrm{T} = \mathrm{I}\alpha = 0.0148\ \mathrm{kg} \cdot \mathrm{m}^2 \cdot 36\frac{\mathrm{rad}}{\mathrm{s}^2} = 0.532593\mathrm{Nm}$$

We round to the number of $0.533\ \mathrm{Nm}$.

Thus, we can conclude that the torque required to overcome the inertia of the rotating parts will be equal to $0.533\ \mathrm{Nm}$.